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Fabrication of CNT based gas sensor using interdigitated gold electrodes

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Abstract:

CNTs gas sensor have been fabricated by deposition of CNTs solution with 0.1M isopropyl alcohol using spin coating with 2000 rpm speed over interdigitated gold electrode formed by DC sputtering with input of 250V and Argon gas pressure of 5×10-2 mbar. The change in resistance of CNTs with different flow rates of CH4 and NH3 gas was monitored in the quartz tube. During the flow of gas, increase in resistance was observed for 2-4 minutes. Resistance declined in the absence of gas. The decline in resistance was more than the original stabilized value when the gas was injected for longer duration of 1.5 hr. The difference in change in resistance pattern for the two different gases predicts the selectivity of the sensor.

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Keywords: CNT, DC sputtering, interdigitated gold electrodes (IGE), Methane, Ammonia.

1. Introduction

CNTs [1] are Graphene sheets that are rolled and depending upon the chirality they take the form of metal, semiconductor and insulator [2]. CNT has its applications ranging from electronic, optics, mechanical, biomedical, energy storage, hydrogen storage and electrical [3][4]. CNTs have been proposed in applications of gas sensors and many such work have been reported [5][6][7][8]. In past several years work on interdigitated electrodes [9][10] for the use of sensors have been done. Several methods have been proposed, such as sputtering [13], lift-off technique [14]. In this paper we report the fabrication of interdigitated electrodes through DC sputtering. CNT is deposited on these electrodes by spin coating technique, and tested for its use as gas sensor for ammonia and methane gas.

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2. Experimental

2.1. FABRICATION OF INTERDIGITATED GOLD ELECTRODES

The IDG electrode have been fabricated on an insulating SiO2 substrate using DC (direct current) sputtering [15][16]. A steel mask with 10 cm^2 and thickness of 2 μm was prepared for patterning the gold electrodes. The uncovered region of the mask had the interdigitated structure with 1.2 mm spacing. The substrate covered with steel mask was kept at the cathode, with gold source at the anode in the DC sputtering chamber. An input bias of around 200-250V was applied which was transformed to -3 KV sputtering bias at the cathode region by the sputtering machine. The Argon gas pressure in the chamber was maintained to about 5×10-2 mbar. As a result of the ions exchange process inside the sputtering chamber with argon inert gas as the carrier, the interdigitated gold electrode was patterned successfully over the SiO_2 layer in span of 30 minutes. The thickness obtained was 1 μm and the spacings between the two electrodes were 1.2 mm.

2.2. CNT DEPOSITION BETWEEN THE ELECTRODES

Commercial available Multi walled CNTs with diameter of 1-5 nm were deposited on to the interdigitated electrodes by the spin coating technique, already an established procedure[17][18]. Following steps were followed:

The CNTs solution with the isopropyl alcohol of 1 molar concentration was ultrasonicated for 1 hour in order to assure good dispersion of the CNT [19][20].The interdigitated electrode was placed on the rotor part of the spin coater. The droplets of the CNTs solution with the isopropyl alcohol were dropped over the interdigitated electrode through the micro pipette. The rotor part of the spin coater was rotated for about 2000 rpm (rotation per minute). As a result CNTs were uniformly deposited in a circular fashion over the interdigitated electrodes. The process was repeated for 3-4 times to get the uniform multilayer structure of the CNTs over the interdigitated electrodes. It was then dried to remove the isopropyl alcohol from the interdigitated electrode. Change in the resistance was observed and measured to be 1.9674 k-Ω which predicts the interconnection between the two electrodes.

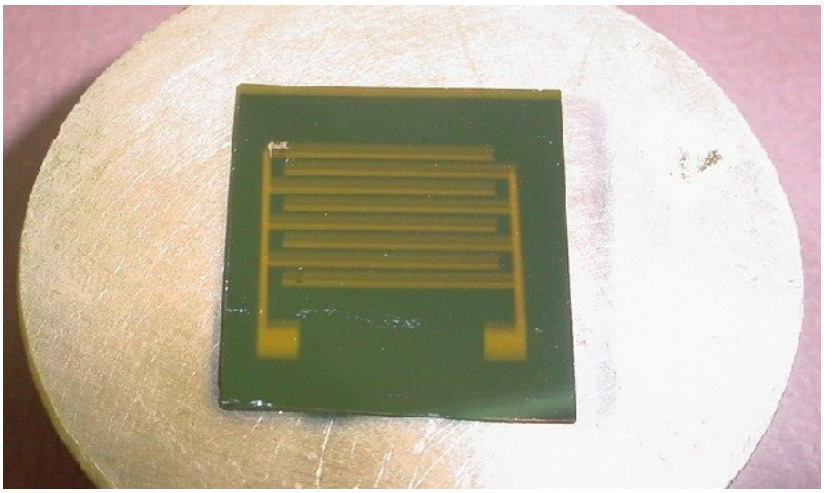


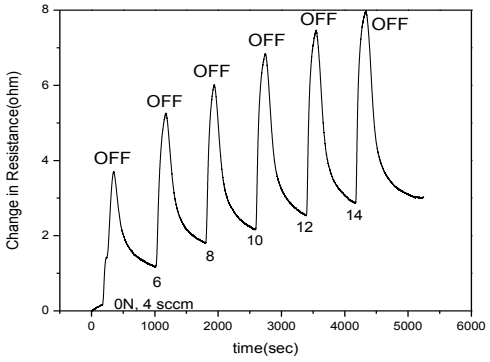
Fig 1: Optical Image of the Interdigitated Electrodes

2.3. CNT DEVICE SENSOR ARRANGEMENT

Two silver wires were connected with the respective gold electrodes using the silver paste. It was then placed in a closed quartz tube with provision for gas flow. The two silver wires connected to the electrode legs were coupled with the multimeter interfaced with the computer to monitor the change in resistance of the CNTs with gas flow [21][22].

3. Results and discussions

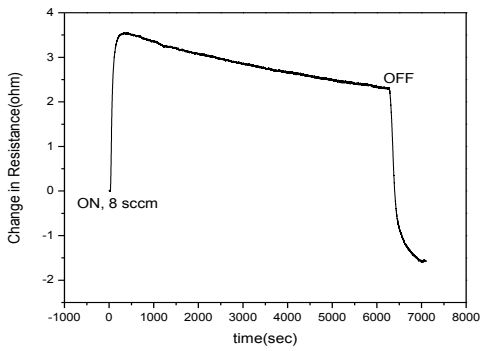
3.1. SENSOR ANALYSIS FOR AMMONIA (NH3)



Scale Y axis: 0 = 1.9674 kohm, 1 unit = 1×10-3 kohm.

Fig 2: Sensor response with change in resistance of CNTs with different flow rates ranging from 4-14 sccm with 2 sccm interval of NH3 gas

The gas flow was injected for 2 minutes for each different increasing flow rates ranging from 4-14 sccm with 2 sccm interval. Fig 2 revels that resistance of CNT increases exponentially and the magnitude increased with increased flow rates of gas. The gas flow was stopped for 10 minutes after the injection of the gas with each increasing flow rates of 4-14 sccm with 2 sccm intervals, decline in the resistance was observed and here too the magnitude increased with the increased rate of gas flow.

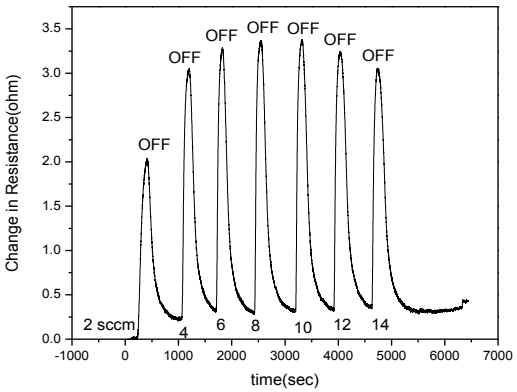


Scale Y axis: 0 = 1.9674 kohm, 1 unit = 1×10-3 kohm

Fig 3: Sensor response with flow rate of 8 sccm of NH3 gas

The gas flow was injected in the tube with flow rate of 8 sccm for around 1.5 hour. Fig 3 reveals an exponential increase in the resistance of the CNTs for 3-4 minutes and then it shown a decline in resistance more than the stabilized value in the preceding time.

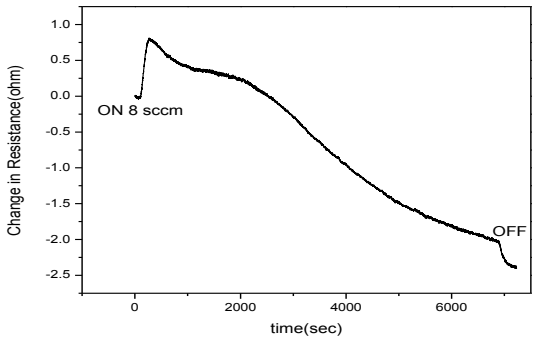
3.2. SENSOR ANALYSIS FOR METHANE (CH4)



Scale Y axis: 0 = 1.9674 kohm, 1 unit = 1×10-3 kohm

Fig 4: Sensor response with different flow rates ranging from 2-14 sccm with interval of 2 sccm of CH4 gas.

The graph looks similar to that of the ammonia gas analysis; it showed an exponential increase in resistance during the flow of gas, and the resistance decline when the gas flow was stopped, magnitude being higher when the rate of gas flow was increased.



Scale Y axis: 0 = 1.9674 kohm, 1 unit = 1×10-3 kohm

Fig 5: Sensor response with flow rate of 8 sccm of CH4 gas

The gas flow was injected in the tube with flow rate of 8 sccm for around 1.5 hour. Fig 3 reveals an exponential increase in the resistance of the CNTs for 3-4 minutes and then it shown a decline in resistance more than the stabilized value in the preceding time. It was observed that the rate of decline in resistance was faster as compared during ammonia gas detection.

The change in resistance of the CNTs between two gold electrodes, with gas flow successfully accounts for gas detection. The increase in resistance for 2-4 min. with injection of gas was due to adsorption of gases. Due to this unsaturated bonding in CNTs tries to become saturated decreasing the number free or mobile electrons. These gases were adsorbed only for 3-4 min. before reaching the adsorption saturation limit, after that they leave off the surface causing decline in resistance. During de-adsorption process it was observed there was increase in number of mobile electrons causing decline in resistance more than the original stabilized value. This predicts the CNTs as physically reactive at the surface level enhancing the probability of its surface to be non uniform and unstable morphology. The difference in change of resistance pattern for CH4 and NH3 gases accounts for the selectivity of the sensor**.**

4. Conclusion

In summary, we have fabricated interdigitated electrodes by sputtering technique, deposited commercial available CNT by spin coating technique. The fabricated CNT sensor was then tested with the gases like ammonia, methane. The process was repeated for several flow rates for small time duration and also fixed flow rate for a longer duration of time. Results revealed that CNT showed a good resistance change on exposure of different gas on the surface of CNTs which concludes the good selectivity of the sensor.

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